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A WFUMB COE Project

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● Original Contribution

TRAINING MIDWIVES TO PERFORM BASIC OBSTETRIC POINT-OF-CARE ULTRASOUND IN RURAL AREAS USING A TABLET PLATFORM AND MOBILE PHONE TRANSMISSION TECHNOLOGY—A WFUMB COE PROJECT

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Abstract—Point-of-care ultrasound (POCUS) has become a topical subject and can be applied in a variety of ways with differing outcomes. The cost of all diagnostic procedures including obstetric ultrasound examinations is a major factor in the developing world and POCUS is only useful if it can be equated to good outcomes at a lower cost than a routine obstetric examination. The aim of this study was to assess a number of processes including accuracy of images and reports generated by midwives, performance of a tablet-sized ultrasound scanner, training of midwives to complete ultrasounds, teleradiology solution transmissions of images *via* internet, review of images by a radiologist, communication between midwife and radiologist, use of this technique to identify high-risk patients and improvement of the education and teleradiology model components. The midwives had no previous experience in ultrasound. They were stationed in rural locations where POCUS was available for the first time. After scanning the patients, an interim report was generated by the midwives and sent electronically together with all images to the main hospital for validation. Unique software was used to send lossless images by mobile phone using a modem. Transmission times were short and quality of images transmitted was excellent. All reports were validated by two experienced radiologists in our department and returned to the centers using the same transmission software. The transmission times, quality of scans, quality of reports and other parameters were recorded and monitored. Analysis showed excellent correlation between provisional and validated reports. Reporting accuracy of scans performed by the midwives was 99.63%. Overall flow turnaround time (from patient presentation to validated report) was initially 35 min but reduced to 25 min. The unique mobile phone transmission was faultless and there was no degradation of image quality. We found excellent correlation between final outcomes of the pregnancies and diagnoses on the basis of reports generated by the midwives. Only 1 discrepancy was found in the midwives' reports. Scan results versus actual outcomes revealed 2 discrepancies in the 20 patients identified as high risk. In conclusion, we found that it is valuable to train midwives in POCUS to use an ultrasound tablet device and transmit images and reports *via* the internet to radiologists for review of accuracy. This focus on the identification of high-risk patients can be valuable in a remote healthcare facility. (E-mail: sudhir.vinayak@aku.edu) © 2017 The Authors. Published by Elsevier Inc. on behalf of World Federation for Ultrasound in Medicine & Biology. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Key Words: Ultrasound, Obstetrics, Midwives, Training, Teamwork, High-risk pregnancies, Screening, Teleradiology.

INTRODUCTION

Antenatal ultrasound has proven to be an extremely useful examination during pregnancy. In realization of its importance in clinical care, the International Federation of Gynecology and Obstetrics (FIGO 2014) recently issued a recommendation that all preg-

nant women should be offered at least 2 ultrasound examinations at 11 + 0–13 + 6 wk and at 18–22 wk (FIGO 2014). Indeed, this is the practice in most developed economies; however, many women in low resource regions especially in sub-Saharan Africa will still go through pregnancy without the benefit of even a single ultrasound examination (Ostensen 2000; Rijken et al. 2009; Sippel, et al. 2011). Unfortunately, regions with low access to this technology contribute significantly to the global burden of perinatal morbidity and mortality.

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In the developing world, antenatal ultrasound is available to only a few privileged people in urban centers; yet the majority of the population live in rural areas with little or no access to diagnostic services, and patients have to travel long distances to access medical care. The cost of ultrasound machines has decreased significantly in the past few years and good-quality imaging can be performed using portable machines that run off batteries, which can be charged using solar power. As such, ultrasound is inexpensive, easy to perform and train personnel in its use. Ultrasound machines are robust; thereby making them easy to take to a rural setting where patients need it most. Ultrasound as an imaging modality has many advantages such as image resolution and definition of anatomy, real-time imaging that allows immediate diagnosis which can be precisely controlled by the operator, wide availability of ultrasound equipment and the existence of multiple simple and straightforward practical techniques that cover a broad range of applications (Allan et al. 2011). Furthermore, the availability of ultrasound in highly compact form allows its use in virtually any location where medical care can be delivered (Jones et al. 2009).

Another challenge in developing countries is the extreme shortage of sonographers and doctors trained to perform ultrasound. This shortage is so significant that even urban areas have an acute shortage; ironically, the number of trained nurses and midwives is far greater. An innovative proposal would be to train midwives to perform point-of-care ultrasound (POCUS) to identify high-risk pregnant patients who can then be referred to regional hospitals for further management. This arrangement would be similar to a triage service that identifies patients requiring further medical management. A key feature of POCUS is that it is not a replacement for comprehensive ultrasound practice but a focused ultrasound examination, often in suboptimal conditions, with the goal being to identify high-risk patients. Therefore, POCUS training and practice needs to reflect the nuances of the particular region it covers (Dietrich et al. 2015). The specific applications and training methodology should be tailored to suit the local environment (Nathan et al. 2016).

This pilot project in Kenya focuses on training midwives to perform basic ultrasound to identify high-risk pregnancies. The project requires identifying midwives who are up to the task of learning and performing ultrasonography, compiling and implementing a training curriculum, establishing ultrasound facilities, transmitting images and having Radiologists validating reports.

The tablet platform used is light, portable and has the same resolution as a standard ultrasound machine. In addition, the tablet platform has built-in software to transmit images *via* the internet. The inclusion of this

software is an advantage over a routine ultrasound machine, which does not usually include transmission capability because the additional software is cost prohibitive. The transmission software compresses the images to make smaller *packets* that are easy to transmit and can be uncompressed after transmission. A lossless image is the final product whereby it does not lose any resolution during transmission; as opposed to lossy images that lose some resolution when uncompressed. Success of the pilot project may be replicated on a national scale to provide cost-effective antenatal care for women in rural areas.

OBJECTIVES

The primary objectives of our project are to: (i) determine the accuracy of images and reports generated by trained midwives performing basic obstetric ultrasound examinations at our satellite sites; (ii) evaluate performance of a tablet-sized ultrasound scanner VISIQ (Philips Ultrasound, Inc., Bothell, WA, USA) as sole ultrasound system for this obstetric *triage* system (Fig. 1).

The secondary objectives of our project are to: (i) implement a teleradiology solution, including protocols to guide communication between sites as a quality control mechanism to review studies from newly trained frontline healthcare providers; (ii) identify components of the education and teleradiology model, which need to be further improved to facilitate ultrasound examinations by inexperienced users.

MATERIALS AND METHODS

Design

This was a prospective cross-sectional study. A curriculum was designed to teach midwives who had no previous training in ultrasound to independently work at a healthcare facility to identify high-risk pregnancies. Images and provisional reports were sent to the main hospital using an innovative online teleradiology solution for



Fig. 1. VISIQ ultrasound machine with transducer (Philips Ultrasound, Inc., Bothell, WA).

validation. This pilot project, if proven successful, may be used to justify a much larger nationwide project. Ethics approval was obtained from the hospital's IRB [No. 2014/REC-58(v2)].

Training protocol

Three midwives with no prior exposure to ultrasound practice (to avoid pre-exposure bias) were chosen from three satellite centers. Midwives were selected because the pilot study is focused on obstetric ultrasound and they constitute frontline healthcare providers in this field within the community healthcare system. All three midwives had less than 3 years experience in midwifery and they volunteered to be trained, which showed their willingness and interest in learning new skills. None of them had any previous experience in performing ultrasound or interpreting ultrasound images.

The three satellite clinics from which each midwife was selected were 20-, 120- and 400-km away from the main study center at the hospital. These are point-to-point distances; whereas the road travel distances were much longer. Short, medium and long distances were specifically chosen to assess transmission times in relation to distance during the transfer of images and reports using teleradiology.

The process of delivering and implementing the course was as follows:

1. An e-learning module (Philips Medical Solutions) was made accessible to each midwife at her respective site. This module covered basic knowledge including an introduction to general principles of ultrasound, physics of ultrasound and ultrasound specific to obstetrics. Each midwife had to pass a test at the end of the module to proceed with the course. The pass mark was set at 100% and each midwife could retake the test up to 5 times.
2. At the main study center, the three midwives were introduced to ultrasound equipment, and an experienced sonographer delivered a series of didactic lectures on the basis of the curriculum, using PowerPoint (Microsoft, Redmond, WA, USA). This covered the entire curriculum, comprising general and obstetric ultrasound. The lectures were followed by hands-on practical experience, which the users said they thoroughly enjoyed.

Participants were also introduced to Philips Connected Care (CCC, Philips Medical Solutions), a teleradiology and remote reporting solution for consultation and validation of reports to positively impact the quality of antenatal care.

The training period was for 4 wk and each d began with a 1-h lecture, followed by 6 h of practical hands-on work and ended with another 1-h lecture in the eve-

ning. Initially we did not know how long it would take to train the midwives so we had to assess them for competency as training progressed.

Week 1: Introduction to ultrasound knobology was followed by hands-on scanning of phantoms. By the end of the week the midwives had begun observing scans performed by qualified sonographers.

Week 2: The midwives began to perform some scans under direct observation, which progressed to independent scanning under supervision.

Week 3: Feedback and matters arising were addressed in the lecture room as the practical work continued to progress.

Week 4: Direct observational work in practice skills was performed and an examination was delivered to the midwives. The exit examination was designed to test both written and practical skills.

Week 5: The principle investigator spent time with each midwife and questioned her on various aspects of ultrasound. They each received ultrasonography certification from our program. This took a few days during week 5.

The total training period was just more than 1 mo (the midwives worked approximately 8 h a d for 4 wk, followed by several days of assessment by the principal investigator). During this time, the Information Technology Department tutored the 3 midwives on connectivity application using a cellphone modem and other related practical issues pertaining to the transfer of images and reports from the satellite clinics to and from the main study center.

Patient recruitment and study population

We recruited consecutive gravid patients 18–50 y of age who had consented in writing to having a scan at 1 of our 3 antenatal clinics. They had the right to withdraw at any time without any jeopardy to their medical care. It was clearly stated that the primary purpose of the scan was to rule out a high-risk pregnancy. In cases where a high-risk pregnancy was diagnosed, patients were sent to a specialized ultrasound facility for further evaluation.

A sample size of 246 patients was found to adequately power the study for evaluating the accuracy of scanning. The sample size calculation formula was defined as:

$$n = \frac{1.96^2 s^2}{m^2} \quad (1)$$

Where S (standard deviation) is 0.4 and m is the margin of error = 0.05. This calculation is based on the study's primary objective. Whilst all patients were enrolled consecutively, we estimated approximately 5

participants per d would be enrolled in each satellite center with an average of 85 for each center. We eventually scanned 271 patients who met our criteria for evaluation because we increased the sample size to factor in a 10% failure rate.

The study included literate, consenting gravid mothers 18–50 y of age with a gestation of >20 wk. The study excluded any patient presenting with obvious signs of a complication such as vaginal bleeding.

Study procedures

Each participant was informed what a routine ultrasound examination would entail as part of this study. They were assured that no known immediate, delayed or long-term risks existed as a result of ultrasound imaging using the ultrasound output levels and techniques used for this ultrasound examination.

Each midwife:

1. Selected obstetric patients on the basis of the inclusion criteria
2. Ensured selected patients agreed and signed the informed consent form
3. Performed an ultrasound examination using our strict scan protocol
4. Acquired a minimum of nine images listed under Obstetric Ultrasound Examination (Cunningham et al. 2013)
5. Complete the standard protocol reporting template to generate a provisional report
6. Established 3 G connection to Philips CCC software (Philips Medical Solutions) and uploaded the study using VISIQ (Philips Ultrasound, Inc.) weblink/webpage.
7. Asked each patient to complete a brief survey to provide feedback about their scan experience

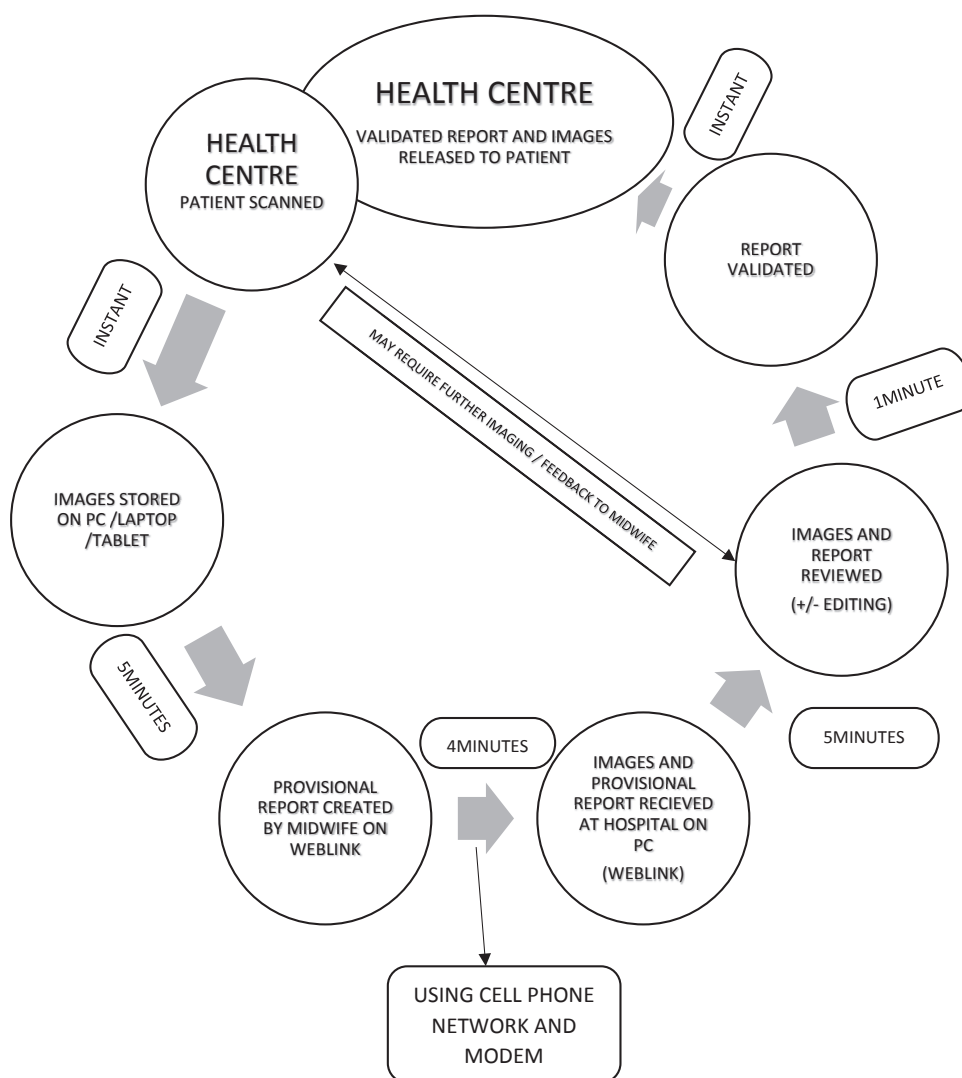


Fig. 2. Study process.

The images and reports were reviewed and validated by 2 radiologists with more than 10 y experience in obstetric ultrasound. The 2 performed the following tasks (Fig. 2):

1. Downloaded images and provisional reports of the studies from the CCC (Philips Medical Solutions) software using an Internet Explorer (Microsoft) browser.
2. Reviewed each examination for adequacy of images as per scan protocol and accuracy of findings entered in the standardized protocol template. Assessment of quality based on reporting and image acquisition was done using a detailed quality assurance form being used currently in the Department of Imaging and Diagnostic Radiology, Aga Khan University Hospital, (Appendix 1).
3. Returned all review comments to the midwife using the same teleradiology system.

During this time, the patient was asked to wait for feedback from the main hospital so she could be re-scanned if further imaging was required. The midwives downloaded the review comments to help improve their standards. They released the validated report to the patient if no further imaging was required. To evaluate the efficiency of the teleradiology system. Transmission times to and from the centers were recorded by the information technology department for purposes of analysis.

Obstetric ultrasound examination

The midwives took specified images and measurements. These included the unborn child's head circumference, abdominal circumference, femur length and heart rate and rhythm. In addition, the midwives measured the placenta location and distance of lower lip from the internal os and estimated the amount of amniotic fluid (obtained from four images, one image for each quadrant).

For the purpose of this study any of the following findings constituted high-risk pregnancies: breech from 34 wk onward, twin gestation, intra-uterine growth restriction, low lying placenta and decreased amniotic fluid. These conditions required referral to a secondary care facility. A survey was conducted in which each patient and her partner, if available, was asked if they were willing to give feedback about the experience of their scan.

RESULTS

All 3 midwives passed the online e-module examination on their first or second attempt. All 3 passed their final exit examination on their first attempt (at the end of week 4). The midwives completed 271 ultrasound

examinations, which were analyzed by the radiologists. The results follow.

All images and corresponding measurements taken by the midwives were in keeping with the standardized criteria prescribed in the methodology. The accuracy of interpretation of images and all corresponding measurements in the report was 99.63%, as illustrated in Table 1. Two hundred and twenty patients could be traced postdelivery to determine the final outcome of their pregnancy. The remaining 51 patients could not be contacted or the final outcome could not be established. Of these 220 patients, 20 had been labeled as high risk and their corresponding final outcomes are illustrated in Table 2.

Three patients had adverse outcomes that had not been detected on ultrasound: (i) Down syndrome. The midwives were not trained to screen for trisomies. (ii) Still birth. Severe ante-partum hemorrhage (cause unknown). We reconfirmed that no evidence of placenta previa was found on scans; placenta was fundal. (iii) Intra-uterine fetal death at 39 wk (cause unknown).

The turnaround time from the end of the scan to validation of the report was approximately 15 min. Overall turnaround time was 35 min at the beginning of the study, which was reduced to 25 min as the study progressed. No issues occurred with the cell phone, model or CCC system (Philips Medical Solutions). No difference in transmission time and no degradation of image quality were found. The stored images were immediately available to the reporting radiologist online.

All 246 patients felt that the process was safe, convenient and reassuring. They all had a better antenatal visit experience and increased confidence in the delivery of care. More spouses accompanied the mothers for the scans compared with those accompanying for a routine antenatal clinic visit. All the mothers reported that the scan fostered a stronger bonding between expecting fathers and their baby.

DISCUSSION

This pilot study had preset goals and its evaluation broadly falls under three main areas of interest: (i) Training of midwives, (ii) ultrasound practice using a tablet platform and (iii) teleradiology. On all three fronts in the opinion of the authors the positive outcomes far outweigh the negatives.

Table 1. Accuracy of image interpretation by the midwives in comparison with radiologists' final report

Patients scanned	Total	Discrepancy	Conformity
Number	271	1	270
Percentage	100	0.37	99.63

Table 2. Outcome of pregnancies classified as high risk

High-risk finding	Number labeled high risk	Outcome match
Breech	4	4
Low placenta <2 cm from os	1	1
Amniotic fluid index <6 cm	2	0
Twins	7	7
IUGR	2	2
Wrong dates	4	4
Total	20	18

Training

We asked practicing midwives from our satellite centers to apply for the course. From the applicants list, we chose those who were based at specific distances from the hospital. We established no set criteria to short-list the aspirants but it was a prerequisite that they had no experience with ultrasound and they were enthusiastic about its outcome.

The online training module was developed by the ultrasound manufacturer (Philips Medical Solutions) and had been previously used for other types of training. The online training module gives a novice basic understanding of the physics of ultrasound and its application. This module was a *must pass* requisite for further training and the participants said that they realized how useful the knowledge was during the subsequent practical course. Being an online course, the midwives had ample time to prepare for the online test and could attempt the test again if they failed. The module was also readily available on CD.

The training was carried out in the main Aga Kahn University Hospital. We had no previous experience training participants with no prior experience in ultrasound, and timelines for the training were unknown. The open-ended timeline had to be assessed toward the end of the training period and several similar trainings have been described by other authors (Hediger et al. 2016; LaGrone et al. 2012; Parker and Harrison 2015; Rijken et al. 2009; Shaw-Battista 2015); yet no data have been published stating an ideal time frame for the training period. Therefore, the length of the training period was not established but rather was based on the skill assessment of the midwives to perform an accurate ultrasound examination.

By the end of the fourth wk it was reasonably clear to the investigators that the midwives were ready to undergo the exit test, allowing study implementation and patient recruitment. Our optimism was confirmed when all the midwives passed the exit written examination at their first attempt. This was followed by a practical hands-on examination to demonstrate their competency to scan confidently; all midwives passed with good ability to scan independently.

Practice

Image data analysis confirmed that the midwives had been adequately trained because no examinations needed further imaging following review by the radiologists. Reporting accuracy of scans performed by the midwives was 99.63% as illustrated in Table 1. The midwives diligently scanned patients with a good understanding of the established protocol and used a standardized template to complete the report.

Validation of images and provisional reports was performed on a standard personal computer with a high-resolution monitor (workstation). Other than a few typographical changes, the midwives were able to confidently report all images. A cell phone was used for communication whenever clarification was required between the radiologist and midwife.

Only one discrepancy (Table 1) was found in the midwives' reports. It was reported as normal or low risk; whereas the radiologist noted a more than 2-wk discrepancy between the gestational age according to last menstrual period and the gestational age by ultrasound. The midwife had correctly taken the measurements but not classified it as a high-risk pregnancy as per the reporting protocol. The patient was reclassified by the radiologist as possible intra-uterine growth restriction for which follow-up imaging was recommended. All examinations reported as high risk by the midwife met our protocol requirements and no cases were downgraded to low risk.

Scan results versus actual outcomes

We set about trying to establish the outcome in all 271 patients who had participated in our study. This was the only sure way of finding out whether the midwives had correctly diagnosed all conditions. Any missed diagnosis or over diagnosis of conditions would then become apparent. We successfully traced 220 patients to delivery and compared their outcomes with the data we had collected. Table 2 compares all 20 high-risk patients with the outcomes of these patients. All the patients labeled as low-lying placenta, breech, twins, intra-uterine growth restriction and wrong dates matched the outcome. We saw a discrepancy in only two patients who were found to have reduced amniotic fluid on ultrasound; however, their pregnancies progressed well and the outcome at delivery was normal. Our method of estimating the quantity of amniotic fluid was the standard method of four-quadrant measurements giving a cumulative depth representing the amniotic fluid index (AFI); our cut-off value was 6. The recommended cut-off is 5 (ACOG 2009).

We re-analyzed the data we had on the two patients with concerning AFI. One had an AFI of 6.47 at 28 wk and 4 d' gestation, which is just above the cut-off for

normal. We placed this patient in the high-risk group to err on the safe side; whereas the protocol would have described the finding as *normal*. The second patient was similar and one of the first few recruited. In retrospect, the AFI was also borderline and measurements had been taken at an early stage of the pregnancy. Both patients had healthy babies and there was no indication of low amniotic fluid at delivery. Rescanning later in pregnancy could have avoided the classification as high risk. We would thus consider revising our protocol for future practice.

Teleradiology

Overall turnaround time (from patient presentation to validated report) was 35 min at most and matched the waiting time of obstetric ultrasound patients within the main radiology department of Aga Khan University Hospital. At the beginning of the study the midwives took approximately 20 min to perform a scan. After about 30 scans, this time reduced to about 10 min, because, as the study progressed, the midwives had gained experience in independent scanning. Therefore, the overall turnaround time reduced from 35 min to 25 min. Scan quality remained the same, regardless of scanning time. These findings are in agreement with observations published by [Hediger et al. \(2016\)](#). The optimized scan time of 10 min as well as maximum scan to validated report time of 35 min reflected the success of the study.

Throughout the study, we had no issues with the cell phone, modem or CCC system (Philips Medical Solutions). The system worked flawlessly, and the cost of the internet bundle (1 GB) per 5 patients was approximately \$1.00 US. The process required a good cell phone signal, which was always available. No appreciable difference in transmission time and no degradation of image quality was experienced regardless of clinical site distance from the main hospital. The midwives stored the images on an electronic device and created a provisional report on web link or web page, which was immediately available to the reporting radiologist online.

Patient satisfaction survey

We carried out a survey of the study participants after the scan had been completed. This was on a voluntary basis and sought to get feedback from participants about their experience of being scanned using this system. We received feedback from 246 patients and without exception they all felt it was safe, convenient and reassuring to have the scan. The patients also gave very positive feedback about having an ultrasound scan in addition to a routine antenatal visit examination. The mothers found it very reassuring to see the baby and hear the heartbeat. This study showed improved patient satisfaction for all

patients at their antenatal visit and increased confidence in the delivery of care for all the mothers. Many more spouses than usual accompanied the mothers for the scans compared with those accompanying for a routine antenatal clinic visit; this was subjective and not measured. All the mothers reported that the scan fostered a stronger bonding between expecting fathers and their babies. These findings mirror those by other studies ([Øyen et al. 2016](#)).

Limitation

Evaluating only three midwives is a limitation of the study. A resultant risk of selection bias was unaccommodated. A much larger sample will be required to assess whether the training was indeed perfect.

The only good reference standard in assessing the accuracy of ultrasound is a subsequent examination of an experienced sonographer blinded to the previous scan. This would have been the best way to assess the training aspect of this study.

CONCLUSION

To compensate for a shortage of sonologists and sonographers in low-income countries, training midwives to undertake routine focused obstetric scanning for identification of high-risk pregnancies is a very viable option. Using ultrasound, experienced midwives can be taught to confidently perform obstetric ultrasound examinations confidently and reassure patients with healthy babies. Working as a team with radiologists can be particularly valuable to midwives in remote healthcare facilities in middle- to low-income countries. With modern technology, the exchange of images between healthcare centers and referral hospitals the use of cell phones is both inexpensive and effective.

RECOMMENDATIONS

The training format and timelines used in this study can be a guide to standardize obstetric ultrasound training of midwives. The reclassification of high-risk pregnancies, particularly regarding placenta previa and amniotic fluid measurement assessment should be done to restrict this evaluation to a particular stage of gestation. Because of the importance of obstetric ultrasonography and the mismatch between demand and supply in middle- and low-income countries, multidisciplinary teamwork between radiologists and other qualified healthcare providers should be optimized. This, coupled with robust teleradiology technology such as that used in this study can be utilized to increase access in a much-needed environment.

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SUPPLEMENTARY DATA

Supplementary data related to this article can be found online at <http://dx.doi.org/10.1016/j.ultrasmedbio.2017.05.024>.

REFERENCES

- ACOG Practice Bulletin No. 101: Ultrasonography in pregnancy. *Obstet Gynecol* 2009;113:451–461.
- Allan A, Bedford N, Nicholls B, Denny N. Comparing ultrasound and nerve stimulation: Time to ask the question? *Anaesthesia* 2011;66:222–223.
- Cunningham F, Leveno KJ, Bloom SL, Spong CY, Dashe JS, Hoffman BL, Casey BM, Sheffield JS. *Fetal imaging, Williams obstetrics*. 24th edition. New York: McGraw-Hill 2013.
- Dietrich CF. EFSUMB guidelines 2015 on interventional ultrasound. *Med Ultrason* 2015;17:521–527.
- FIGO Working Group on Best Practice in Maternal–Fetal Medicine. Best practice in maternal–fetal medicine. *Int J Gynaecol Obstet* 2015;128:80–82.
- Hediger ML, Fuchs KM, Grantz KL, Grewal J, Kim S, Gore-Langton RE, Buck Louis GM, D’Alton ME, Albert PS. Ultrasound quality assurance for singletons in the national institute of child health and human development fetal growth studies. *J Ultrasound Med* 2016;35:1725–1733.
- Jones JA, Sargsyan AE, Barr YR, Melton S, Hamilton DR, Dulchavsky SA, Whitson PA. Diagnostic ultrasound at MACH 20: Retroperitoneal and pelvic imaging in space. *Ultrasound Med Biol* 2009;35:1059–1067.
- LaGrone LN, Sadasivam V, Kushner AL, Groen RS. A review of training opportunities for ultrasonography in low and middle income countries. *Trop Med Int Health* 2012;17:808–819.
- Nathan RO, Swanson JO, Swanson DL, McClure EM, Bolamba VL, Lokangaka A, Pineda IS, Figueroa L, Lopez-Gomez W, Garces A, Muyodi D, Esamai F, Kanaiza N, Mirza W, Naqvi F, Saleem S, Mwenechanya M, Chiwila M, Hamsumonde D, Wallace DD, Franklin H, Goldenberg RL. Evaluation of focused obstetric ultrasound examinations by health care personnel in the Democratic Republic of Congo, Guatemala, Kenya, Pakistan, and Zambia. *Curr Probl Diagn Radiol* 2016;46:210–215.
- Ostensen H. Developing countries. *Ultrasound Med Biol* 2000;26(Suppl. 1):S159–S161.
- Øyen L, Aune I. Viewing the unborn child- pregnant women’s expectations, attitudes and experiences regarding fetalultrasound examination. *Sex Reprod Healthcare* 2016;7:8–13.
- Parker PC, Harrison G. Educating the future sonographic workforce: Membership survey report from the British Medical Ultrasound Society. *Ultrasound* 2015;23:231–241.
- Rijken MJ, Lee SJ, Boel ME, Papageorghiou AT, Visser GH, Dwell SL, Kennedy SH, Singhasivanon P, White NJ, Nosten F, McGready R. Obstetric ultrasound scanning by local health workers in a refugee camp on the Thai-Burmese border. *Ultrasound Obstet Gynecol* 2009;34:395–403.
- Shaw-Battista J, Young-Lin N, Bearman S, Dau K, Vargas J. Interprofessional obstetric ultrasound education: Successful development of online learning modules; case-based seminars; and skills labs for registered and advanced practice nurses, midwives, physicians, and trainees. *J Midwifery Womens Health* 2015;60:727–734.
- Sippel S, Muruganandan K, Levine A, Shah S. Review article: Use of ultrasound in the developing world. *Int J Emerg Med* 2011;4:72.